others are subcuneiform. The inferior canines are considerably larger than the incisors. The latter are regular and do not overlap each other; the second and third inferior premolars have well-developed basal lobes anteriorly and posteriorly. The heel of the sectorial is well developed. The tubercular is very small.

The form of the skull is short and wide; the zygomata are much expanded; and the profile is very convex. The muzzle is short, and the orbits are rather large. The interorbital region is wide and convex; and the postorbital processes are robust, acuminate, and directed downwards. The infraorbital foramen is very large. The apices of the premaxillary bones are elongate, but do not reach the frontals. The nasals are rounded posteriorly. The sagittal crest is prominent, and the inion elevated. The posttympanic process is short; and the paroccipital is short and is directed backwards. The cranium is constricted behind the orbits. The mandibular ramus is low posteriorly; and the anterior inferior flange is well developed, but not large.

Measurements.

	metre.
Length of skull on base	·140
Width of skull, measured below	·111
Length of palate	·060
Width of palate between posterior angles of sectorials	·062
Width of palate between canines	·026
Length of skull to front of orbits (axial)	·050
Vertical diameter of orbit	·031
Interorbital width (least)	·045
Elevation of inion from foramen	·032
Length of inferior molar series	·050
Length of inferior sectorial	·018
Length of base of inferior first premolar	·055
Depth of ramus at sectorial	·016
Depth of ramus at first premolar	·021
Depth of ramus at flange	·026

From the Truckee beds of John Day River, Oregon.

[To be continued.]

V.—*On the Geological Distribution of the Rhabdophora.*

By Charles Lapworth, F.G.S. &c.

Part II. Data.

[Continued from vol. iv. p. 431.]

Silurian System (*Upper Silurian of Murchison*).

Of the many suggested modifications of Murchison's latest

scheme of classification of the Lower Palæozoic rocks not one is perhaps more important, or more certain eventually to be adopted by geologists in general, than the transference of the theoretical line of demarcation between his Lower and Upper Silurian from the middle of the Lower Llandovery to the base of that formation. The immediate adoption of this new divisional line by those who rely more especially upon marked physical evidence is hardly to be expected. In the typical district of Llandovery Murchison's plan of classification appears at first sight the only one possible, as there seems to be an uninterrupted sequence from the Llandeilo into the Lower Llandovery. Not only so, but the magnitude of the stratigraphical discordance below the *Pentamerus*-Grits and Limestones of the Upper Llandovery, where Murchison draws his line of demarcation, is clear and unequivocal from Wenlock to Llangadock.

On the other hand, however, the Lower Llandovery grits, which, in Central Wales, follow immediately upon the dark shales of the Upper Bala, afford unmistakable evidence of important and widespread changes in the physical condition of the sea-bottom at the advent of the Llandovery epoch. Even in the typical district of Llandovery itself this change, according to Messrs. Salter and Aveline, is, probably, marked by an unconformability. Throughout the basin of the Dee the Lower Llandovery beds, according to the most recent researches of Professor Hughes and others, retain their coarse arenaceous character. The relations of the Bala shales to similar grits at Conway appear to me impossible of interpretation except on the hypothesis of an unconformability or overlap at the base of the latter. The most convincing argument, however, in favour of the proposed change is found in the fact that, if we except the typical district of the higher portion of the valley of the Towey, the most distinct physical and palæontological break in the strata that lie between the Arenig and the Ludlow is that at the summit of the Bala formation and its extra-British equivalents. In Scotland, for example, the only palæontological break of any magnitude is that at the base of the equivalent of the Lower Llandovery —the representatives of the Lower Llandovery, Upper Llandovery, and Tarannon graduating imperceptibly the one into the other. In Scandinavia the same rule holds good generally, though there are beds of passage where the Ordovician and Silurian forms are for a time commingled. I believe that the same rule obtains in Bohemia and Thuringia; but our present evidence is too defective to enable us to bring forward decisive proofs. In America (Anticosti ex-

cepted) the physical and palæontological changes at the base of the equivalents of the Lower Llandovery are so marked and of such systematic importance, that American geologists have universally drawn the boundary line between their Lower and Upper Silurian systems along this horizon.

Adopting, then, this line as the base of the true Silurian, we have next to determine the most natural limits of the component formations of that system. Here we have to bear in mind that in the typical area of Shropshire a few feet only of the lowest of the Silurian formations are visible, and even these were not separated by Murchison from the underlying Bala rocks until he was compelled to distinguish them by the discoveries of Sedgwick and M'Coy. And it is now daily becoming more clearly evident that in the same typical area there is, in reality, but a very feeble and degenerate representative of the highest formation of the Silurian rocks of other countries—the wonderfully prolific étages F and G of Bohemia, and the great Helderberg series of North America.

Of the first of the three grand formations into which the Silurian may most naturally be divided, all that is exposed in the typical area of Shropshire are the thin zones of the Henley conglomerate and the *Pentamerus*-Limestone, which lie between the summit of the Bala and the base of the Wenlock shale. In many parts of Wales, however, as is well known, we find three distinct groups of strata in this position, separated from each other by fairly marked unconformabilities. It has generally been the habit to call the first of these subformations by the title of the Lower Llandovery, the second Mayhill or Upper Llandovery, and the third the Tarannon shale. The first is usually believed to be most intimately allied in its palæontological characters to the Bala formation, and the last to be hardly separable from the Wenlock shale. My own researches impel me to the conclusion that these three subformations are far more closely allied to each other than they are to the beds above or below, and that they should be considered as the three consecutive members of a single formation. In the south of Scotland (*Valentia*) these three subformations are recognizable, superposed in conformable sequence, with clear relations to the Bala below and to the Wenlock above, and unitedly covering an area of several thousands of square miles. Until geologists are willing to include the Tarannon in the Llandovery it will therefore be best to speak of this great Scottish formation and its equivalents as the *Valentian* formation, its three divisions, Lower, Middle, and Upper, representing respectively the Lower Llandovery, Upper Llandovery, and Tarannon of Wales and Siluria.

The second natural division of the Silurian system is undoubtedly Murchison's Great Mudstone series, which includes the so-called Wenlock and Lower Ludlow groups, as high as the horizon of the Aymestry Limestone. In Shropshire this great mudstone or *Salopian* formation is by far the most important physical group in the Silurian. Murchison drew the line of demarcation between his Wenlock and Ludlow formations at the Wenlock Limestone. We suspect, however, that this was done less from a palæontological than from an æsthetic point of view, and mainly for the sake of physical symmetry. Murchison admits again and again that his Lower Ludlow is "simply an upward prolongation of the Wenlock shale." The natural boundary is therefore at the summit of this great mudstone group, generally along the line of the Aymestry Limestone, where new physical conditions set in and the rocks contain a comparatively new fauna. Although this improved arrangement destroys the apparent symmetry of the so-called formations of Siluria, I doubt not that its advantages will in time ensure its general adoption. Under this scheme difficulties that have hitherto confronted us in our endeavours to parallel the British and foreign strata of Silurian age would almost wholly disappear; the arrangement of the Welsh strata would lose much of its presently acknowledged artificiality, and approximate much more closely to the order of nature all over the world.

In Shropshire this Salopian or Mudstone formation is overlain by the sandy strata of the Upper Ludlow, the Bone-beds and the Downton Sandstone. For the sake of distinction these may collectively be termed the *Downtonian* formation. Above Llangadock these strata are almost as thick as the Wenlock and Ludlow beds united. As a rule, however, they form but a very insignificant representative of the great limestones F and G of Bohemia and the Helderbergs of North America, the Oesel beds of Esthonia, &c. Their relation to the Dingle beds of Ireland and the fossil-bearing *Lower Old Red* rocks of Scotland it is as yet impossible to determine.

Valentian or Llandovery Formation.

Wales.—No Graptolites have hitherto been quoted from the undisputed Llandovery strata of South Wales; nor was I able personally to detect a fragment in my hasty examination of the typical localities during the summer of last year.

I discovered Rhabdophora, however, in abundance in the shales of the so-called Tarannon of the neighbourhood of Conway, North Wales. In the cliffs opposite the picturesque old castle I detected

Climacograptus normalis, *Lapw.*
Diplograptus palmeus, *Barr.*
Retiolites Geinitzianus, *Barr.*
Monograptus priodon, *Bronn.*
—— exiguus, *Nich.*
—— Halli, *Barr.*
Monograptus Becki, *Barr.*
—— galaensis, *Lapw.*
—— Sedgwicki, *Portlock.*
—— fimbriatus, *Nich.*
—— turriculatus, *Barr.*

These are possibly the same beds as the strata near Cerrig-y-druidion, in the basin of the Dee, from which Mr. Marr has recently procured Graptolites, as his list of species includes

Diplograptus palmeus, *Barr.*
Climacograptus scalaris, *His.*
Monograptus lobiferus, *M'Coy.*
Monograptus Sedgwicki, *Portl.*
—— colonus, *Barr.*

Lake District.—In the Lake District the Skellgill or Llandovery rocks (Coniston Mudstones) afford Rhabdophora in great abundance. At the typical locality of Skellgill there are two distinct zones of Graptolite-bearing beds. In the lowest (*tenuis*) zone I have detected

Diplograptus folium, *His.*
—— sinuatus, *Nich.*
—— confertus, *Nich.*
—— tamariscus, *Nich.*
Climacograptus normalis, *Lapw.*
Retiolites perlatus, *Nich.*
Monograptus gregarius, *Lapw.*
Monograptus argutus, *Lapw.*
—— spiralis, *Geinitz.*
—— Sedgwicki, *Portl.*
—— tenuis, *Portl.*
—— cyphus, *Lapw.*
—— fimbriatus, *Nich.*
Rastrites peregrinus, *Barr.*

The higher (or *argenteus*) zone has afforded me

Diplograptus Hughesi, *Nich.*
—— sinuatus, *Nich.*
—— tamariscus, *Nich.*
Climacograptus normalis, *Lapw.*
Diplograptus folium, *His.*
Rastrites peregrinus, *Barr.*
Monograptus argenteus, *Nich.*
Monograptus Hisingeri, *Carr.*
—— lobiferus, *M'Coy.*
—— attenuatus, *Hopk.*
—— gregarius, *Lapw.*
—— argutus, *Lapw.*
—— leptotheca, *Lapw.*
—— fimbriatus, *Nich.*

From beds at Knock near Dufton, higher than the typical *argenteus* zone, *Monograptus exiguus*, Nich., and *Rastrites distans*, Lapw., were collected by Prof. Nicholson and myself in 1874. From a thin black seam in the Pale Shales above we procured a *Monograptus* allied to *M. Halli*, Barr.

In addition to many of the foregoing, Prof. Nicholson * quotes from the Coniston Mudstones the following forms :—

Diplograptus vesiculosus, *Nich.*
—— pristis, *His.*
Diplograptus putillus, *Hall.*
—— angustifolius, *Hall.*

The first named probably occurs in the lowest zone; the rest may be new species.

Scotland.—The south of Scotland contains the most prolific Graptolite-bearing beds of Llandovery age yet discovered in Britain. These are the well-known Birkhill shales of the

* Nicholson, Quart. Journ. Geol. Soc. 1868, p. 523.

Moffat district. They break up very naturally into two main divisions, each with several subordinate zones*.

In the deepest zones of the Lower Birkhill we meet with

Diplograptus acuminatus, *Nich.*
—— vesiculosus, *Nich.*
—— modestus, *Lapw.*
Climacograptus normalis, *Lapw.*
Climacograptus innotatus, *Nich.*
Monograptus tenuis, *Portl.*
—— attenuatus, *Hopk.*

Its highest (*gregarius*) zone is crowded with

Diplograptus modestus, *Lapw.*
—— physophora, *Nich.*
—— folium, *His.*
—— tamariscus, *Nich.*
Climacograptus normalis, *Lapw.*
—— rectangularis, *M'Coy.*
Monograptus tenuis, *Portl.*
—— attenuatus, *Hopk.*
—— spiralis, *Gein.*
Monograptus argutus, *Lapw.*
—— cyphus, *Lapw.*
—— Sandersoni, *Lapw.*
—— concinnus, *Lapw.*
—— lobiferus, *M'Coy.*
—— triangulatus, *Harkn.*
—— leptotheca, *Lapw.*
Rastrites peregrinus, *Barr.*

The Upper Birkhill beds afford

Diplograptus tamariscus, *Nich.*
—— sinuatus, *Nich.*
—— Hughesi, *Nich.*
—— palmeus, *Barr.*
Climacograptus normalis, *Lapw.*
—— tectus ? *Barr.*
Retiolites perlatus, *Nich.*
Monograptus runcinatus, *Lapw.*
—— intermedius, *Carr.*
—— concinnus, *Lapw.*
—— Halli, *Barr.*
Monograptus tenuis, *Portl.*
—— attenuatus, *Hopk.*
—— spiralis, *Geinitz.*
—— lobiferus, *M'Coy.*
—— Clingani, *Carr.*
—— Sedgwicki, *Portl.*
—— gregarius, *Lapw.*
—— Hisingeri, *Carr.*
Rastrites peregrinus, *Barr.*
—— fugax, *Barr.*
—— distans, *Lapw.*

The Birkhill beds are succeeded by the vast series of grits, flagstones, and shales which I have denominated the Gala group †. To this group properly belong also the Hawick rocks, which are distinctly inferior to the Riccarton or Wenlock strata of Kirkcudbright and Roxburgh. The Rhabdophora I have collected from the *Gala rocks* of the Eastern districts include

Climacograptus normalis, *Lapw.*
Diplograptus palmeus, *Barr.*
Retiolites obesus, *Lapw.*
—— Geinitzianus, *Barr.*
Rastrites maximus, *Carr.*
—— distans, *Lapw.*
Monograptus runcinatus, *Lapw.*
—— concinnus, *Lapw.*
—— Sedgwicki, *Portl.*
—— Becki, *Barr.*
—— Salteri, *Geinitz.*
Monograptus Hisingeri, *Carr.*
—— Halli, *Barr.*
—— turriculatus, *Barr.*
—— exiguus, *Nich.*
—— galaensis, *Lapw.*
—— Barrandei, *Suess.*
—— crispus, *Lapw.*
—— priodon, *Bronn.*
—— spiralis, *His.*
Cyrtograptus Grayæ, *Lapw.*

* Lapworth, Quart. Journ. Geol. Soc. 1878, p. 328 &c.
† Lapworth, Geological Magazine, 1870, p. 204.

Girvan.—In the Girvan district, the Penkill group, which is the representative of the Valentian or Llandovery of Wales, is composed of the three well-marked consecutive subdivisions of the *Mulloch-Hill beds*, *Saugh-Hill beds*, and *Penkill beds*.

The *Mulloch-Hill beds* consist of a mass of highly fossiliferous sandstones and shales, with a coarse conglomerate at the base. Brachiopods are especially abundant; but Graptolites are excessively rare. The only forms I have collected are

Climacograptus normalis, *Lapw.*
Diplograptus acuminatus, *Nich.*
Monograptus tenuis, *Portl.*

The Saugh-Hill beds consist of flagstones and grits with coarse conglomerates and thick zones of grey shales, locally crowded with well-preserved Rhabdophora. *Pentamerus* occurs in millions in the conglomerates and limestones, while the shales of the group on both sides of the Girvan Water are crowded with the following Birkhill Graptolites:—

Diplograptus modestus, *Lapw.*
—— Hughesi, *Nich.*
—— tamariscus, *Nich.*
—— folium, *His.*
Climacograptus normalis, *Lapw.*
Retiolites perlatus, *Nich.*
Rastrites peregrinus, *Barr.*
Monograptus Sedgwicki, *Portl.*
—— cyphus, *Lapw.*
Monograptus intermedius, *Carr.*
—— gregarius, *Lapw.*
—— lobiferus, *M'Coy.*
—— attenuatus, *Hopk.*
—— leptotheca, *Lapw.*
—— tenuis, *Portl.*
—— Hisingeri, *Carr.*
—— fimbriatus, *Nich.*
—— Salteri, *Geinitz.*

The highest division, or *Penkill beds* proper, includes the representatives of the Gala and Tarannon groups. The lowest beds (*the Crossopodia-Shales*) consist of purple and green mudstone with a few Graptolites, principally

Monograptus galaensis, *Lapw.*
—— Halli, *Barr.*
—— exiguus, *Nich.*
—— Hisingeri, *Carr.*
Monograptus runcinatus, *Lapw.*
—— Sedgwicki, *Portl.*
—— spiralis, *Geinitz.*
Diplograptus palmeus, *Barr.*

The highest beds (*Priodon Flags and Grits*) afford

Monograptus galaensis, *Lapw.*
—— Halli, *Barr.*
—— Hisingeri, *Carr.*
—— Sedgwicki, *Portl.*
Monograptus priodon, *Bronn.*
—— concinnus, *Lapw.*
Cyrtograptus Grayæ, *Lapw.*
Retiolites Geinitzianus, *Barr.*

Ireland.—The only Irish Graptolite-bearing rocks of Llandovery age as yet carefully studied are the Silurian rocks of County Down. From the *Coal-pit Bay beds* that follow the equivalents of the Hartfell shales on the shores of Belfast Lough Mr. Swanston* has collected the following Birkhill species:—

* Swanston, Trans. Belfast Nat.-Hist. Field-Club, Appendix, 1876–77.

Climacograptus normalis, *Lapw.*
Retiolites perlatus, *Nich.*
Diplograptus vesiculosus, *Nich.*
—— folium, *His.*
—— Hughesi, *Nich.*
—— tamariscus, *Nich.*
—— sinuatus, *Nich.*
—— modestus, *Lapw.*
Dimorphograptus Swanstoni, *Lapw.*
Cephalograptus cometa, *Gein.*
Monograptus attenuatus, *Hopk.*
—— tenuis, *Portl.*
Monograptus Sandersoni, *Lapw.*
—— argutus, *Lapw.*
—— gregarius, *Lapw.*
—— concinnus, *Lapw.*
—— leptotheca, *Lapw.*
—— cyphus, *Lapw.*
—— Hisingeri, *Carr.*
—— Sedgwicki, *Portl.*
—— spiralis, *Geinitz.*
—— fimbriatus, *Nich.*
—— triangulatus, *Harkn.*
Rastrites peregrinus, *Barr.*
—— fugax ?, *Barr.*

Higher strata, equivalent in all probability to the Gala and Tarannon formations of Britain, occur near Teiveshilly and other localities on Strangford Lough. From these Mr. Swanston* and the officers of H.M. Geological Survey† have collected

Monograptus Hisingeri, *Carr.*
—— M'Coyii, *Lapw.*
—— galaensis, *Lapw.*
—— riccartonensis, *Lapw.*
—— crispus, *Lapw.*
Monograptus priodon, *Bronn.*
—— proteus, *Barr.*
—— spiralis, *His.*
—— turriculatus, *Barr.*
—— Barrandei, *Suess.*

From the higher (Llandovery) portions of his Pomeroy rocks, Portlock figures in his well-known work‡ the following forms:—

Monograptus Sedgwicki, *Portl.*
—— tenuis ?, *Portl.*
Monograptus turriculatus, *Barr.*
Diplograptus folium, *His.*

together with others it is as yet impossible to identify. I have myself collected from these beds, in addition,

Monograptus gregarius, *Lapw.*
Monograptus discretus, *Nich.*

Mr. Swanston has lately forwarded me from the same beds

Monograptus cyphus, *Lapw.*
—— attenuatus, *Hopk.*
Monograptus leptotheca, *Lapw.*
—— intermedius, *Carr.*

Similar forms are present at Lesbellaw§ and other localities in the west of Ireland.

Sweden.—The *Trinucleus* (Upper Bala) Schists of Scania and Westrogothia are followed immediately by the Brachiopod-Schist—strata very prolific in Testacea, but as yet apparently barren of Graptolites. They stand approximately in the place of the British Lower Llandovery and are succeeded

* Swanston, *loc. cit. suprà.*
† Baily, Explanation of Sheets, Geological Survey of Ireland.
‡ Portlock, Geological Report Tyrone, plate xix.
§ Ibid.

by the *Lobiferus* and *Retiolites* beds, which together compose Linnarsson's Upper Graptolite-Schists *.

The *Lobiferus-beds* are locally very prolific in Rhabdophora. In a collection from these strata, as exposed at Hunneberg, kindly sent me by Dr. Lindström, I recognized

Monograptus lobiferus, *M'Coy.*
—— cyphus, *Lapw.*
—— attenuatus, *Hopk.*
—— triangulatus, *Harkn.*
Rastrites capillaris?, *Carr.*
Rastrites hybridus, *Lapw.*
—— peregrinus, *Barr.*
Diplograptus folium, *His.*
—— tamariscus, *Nich.*
Climacograptus normalis, *Lapw.*

In a collection from strata of the same age forwarded to Prof. Nicholson† by Mr. Linnarsson, many of the same forms occur, together with

Monograptus Sedgwicki, *Portl.*
—— gregarius, *Lapw.*
Monograptus Hisingeri, *Carr.*
Retiolites perlatus, *Nich.*

From the *Lobiferus*-beds of Kongslena in Westrogothia Mr. Linnarsson ‡ has published

Monograptus lobiferus, *M'Coy.*
—— Hisingeri, *Carr.*
—— Sandersoni, *Lapw.*
—— Sedgwicki, *Portl.*
—— spiralis, *Geinitz.*
—— triangulatus, *Harkn.*
Rastrites peregrinus, *Barr.*
Diplograptus palmeus, *His.*
—— modestus, *Lapw.*
—— cometa, *Geinitz.*
—— tamariscus, *Nich.*
Climacograptus rectangularis, *M'Coy.*

From loose boulders, probably of corresponding age, he has subsequently collected

Monograptus runcinatus, *Lapw.*
Rastrites maximus, *Carr.*

and more recently from grey shales, presently identified with the highest *Lobiferus*-beds of Scania, he has obtained the Gala species§

Monograptus crispus, *Lapw.*
Monograptus lobiferus (*M'Coy*).

In Dalecarlia the representatives of the Llandovery strata ‖ appear to be the *Kallholn Schists*, *Stygfors Schists*, and *Leptena*-Limestone of the neighbourhood of Lake Siljan. From the Kallholn schists Dr. Törnquist enumerated the following species in 1873 :—

Climacograptus teretiusculus, *His.*
Diplograptus pristis, *His.*
—— palmeus, *Barr.*
Monograptus Becki, *Barr.*
Monograptus sagittarius, *His.*
—— convolutus, *His.*
Rastrites peregrinus, *Barr.*

* Linnarson, Geological Magazine, June 1876.
† Nicholson, ibid.
‡ Linnarsson, Geol. Fören. Förhandl. 1877, p. 404.
§ Ibid. 1879, p. 255.
‖ Törnquist, Œfvers. af K. Vetensk. Akad. Förhandl. 1874, p. 26.

and from the overlying Stygfors Schists

Diplograptus folium, *His.*
Monograptus priodon, *Bronn.*
—— proteus, *Barr.*
Monograptus convolutus, *His.*
—— turriculatus, *Barr.*
Retiolites Geinitzianus, *Barr.*

In the collection sent me by Dr. Lindström I also recognized

Monograptus Halli, *Barr.*
Monograptus leptotheca, *Lapw.*

from the Stygfors Schists.

The *Lobiferus*-Schists occur also in the island of Bornholm, where they afford the same general assemblage of Rhabdophora.

Thuringia.—Thanks to the industrious researches of Prof. Geinitz and Dr. B. Richter, the Llandovery strata of Saxony and Thuringia have long been famous for their numerous Graptolitidæ. The true Llandovery age of the containing beds has been generally admitted from the first. As a whole the fauna of the so-called *Kiesel-Schiefer* and *Alaun-Schiefer* of this region is essentially Birkhillian; but, judging from the collective fauna, it is clear that strata of Gala or Tarannon age are also present. The group, as a whole, corresponds, both in mineral character and fossils, with Barrande's colonial zone and the lower portion of his zone E *e* 1.

From the Saxon localities Geinitz figures the following species* :—

Diplograptus folium, *His.*
—— palmeus, *Barr.*
—— physophora?, *Nich.* (i. fig. 21).
Cephalograptus cometa, *Geinitz.*
Dimorphograptus Swanstoni, *Lapw.* (i. 25).
Climacograptus rectangularis, *M'Coy.*
Diplograptus vesiculosus, *Nich.* (i. 22, 26).
Monograptus Hisingeri, *Carr.*
—— tenuis, *Portl.*
—— gregarius, *Lapw.* (ii. 25).
Monograptus Halli, *Barr.*
—— lobiferus, *M'Coy.*
—— Sedgwicki, *Portl.*
—— spiralis, *Geinitz.*
—— proteus?, *Barr.*
—— involutus, *Lapw.* (iv. 9).
—— triangulatus, *Harkn.* (v. 6).
—— Nilssoni?, *Barr.* (ii. 18).
Rastrites peregrinus, *Barr.*
—— capillaris, *Carr.* (iv. 19).
—— hybridus, *Lapw.* (v. 17).
—— Linnæi, *Barr.*

The following Gala-Wenlock forms are also figured by Geinitz, but do not appear to occur in association with the foregoing, being found at Grafenwarth and Linda only :—

Monograptus priodon, *Bronn.*
—— bohemicus?, *Barr.*
Monograptus colonus, *Barr.*
Retiolites Geinitzianus, *Barr.*

The whole of the forms enumerated by Geinitz have been subsequently noticed by Dr. Richter in his most valuable

* Geinitz, Die Graptolithen, pls. i.-vi.

papers * on the Graptolites of Thuringia, together with the following species :—

Diplograptus birastrites, *Richter.*
Rastrites urceolus, *Richter.*
Monograptus priodon, *Bronn.*
—— gemmatus, *Barr.*
Monograptus testis, *Barr.*
—— nuntius, *Barr.*
—— turriculatus, *Barr.*

all of which, with the exeption of the first two, are probably from strata of later age than the Birkhill Shales.

Bohemia.—We now enter upon the interesting region of Bohemia, made classic to the student of the Proterozoic rocks by the genius and researches of Barrande. In this area, as already pointed out by Barrande himself, the single division E *e* 1 and the hardly separable zone of the colonies are all that represent the British strata interposed between the summit of the Bala and the base of the Upper Ludlow of Murchison. In other words, the Lower and Upper Llandovery, Tarannon, Wenlock, and Lower Ludlow of Siluria find their equivalents in a small group of carbonaceous and calcareous strata not greatly exceeding 300 feet in thickness. At the present time all the fossils from this diminutive group are united under a single head, and the collective fauna shows of necessity a combination of the characteristics of several distinct British subformations. In Bohemia, precisely as in Britain, the earlier stages of the period of the Third Fauna were marked by repeated elevations and depressions of the sea-bed. An additional local complication was introduced through the prevalence of volcanic action during these early stages, as shown in the abundance of igneous rocks, both interstratified and intrusive, with which the fossiliferous strata are associated. The unconformabilities, overlaps, faults, and folds pointed out by Barrande in these strata are, in all probability, accompanied by a host of other physical accidents as yet undetected. When these physical complications shall have been more perfectly unravelled, and the fossils of the beds classified zone by zone, I feel assured that the anomalies which now appear, on a cursory view, to be most naturally accounted for on the hypothesis of successive interchanges of distinct faunas will wholly disappear, and that, as our knowledge of the rocks and fossils of the Proterozoic age increases, the strata of the symmetrical Bohemian basin will be found to admit of minute and satisfactory comparison with those of Britain.

* Richter, Zeitschrift d. deutsch. geol. Gesellschaft, vols. for 1850, 1851, 1853–1871, &c.

Barrande's first list of his species of the colonies is as follows :—

Monograptus priodon, *Bronn.*
—— bohemicus, *Barr.*
Monograptus Rœmeri, *Barr.**
—— colonus, *Barr.*

a very probable association, but one which (as we shall subsequently show) would in Britain be at once set down as probably existent at the Wenlock period. A fauna distinctly of far older date is given in the extended Catalogue of the Colonial Graptolites printed in the fourth part of the 'Défense des Colonies.' From the Colonie d'Archiac, Barrande † enumerates the following species (exclusive of undescribed forms) :—

Rastrites peregrinus, *Barr.*
Diplograptus folium, *His.*
Monograptus spinigerus, *Nich.*
—— Hisingeri, *Carr.*
—— nuntius, *Barr.*
Monograptus priodon, *Bronn.*
—— Nilssoni, *Barr.*
—— Becki, *Barr.*
—— colonus, *Barr.*
—— bohemicus, *Barr.*

As a whole this is a group of forms that might be looked for at the very base of the Gala or Tarannon group. There are, however, two forms, *M. colonus*, Barr., and *M. bohemicus*, Barr., which are not met with in Britain or Scandinavia until we reach the Wenlock shale. They are, however, represented in the much earlier Gala rocks by the allied forms *M. galaensis*, Lapw., and *M. concinnus*, Lapw.

In the *Colonie Haidinger* the following forms are present :—

Rastrites peregrinus, *Barr.*
Diplograptus palmeus, *Barr.*
Monograptus Becki, *Barr.*
—— bohemicus, *Barr.*
Monograptus colonus, *Barr.*
—— Nilssoni, *Barr.*
—— proteus, *Barr.*
—— spiralis, *Gein.*

an assemblage clearly of the same general geological date as that in the Colonie d'Archiac.

From the *Colonie Krejči* the only forms enumerated by Barrande are

Monograptus bohemicus, *Barr.*
—— colonus, *Barr.*
Monograptus priodon, *Bronn.*
—— Rœmeri, *Barr.*

These are Barrande's original Colonial forms, and, as already hinted, suggest a Wenlock age for this special colony.

The shaly zone E *e* 1, at the base of the series of strata containing the Third Fauna of Barrande, affords precisely the same general group of Graptolites as the typical Colonies

* Barrande, Grapt. de Bohême, p. 18.
† Barrande, Défense des Colonies, iv. p. 126.

themselves. The whole of the forms hitherto published by Barrande from this zone are given in the subjoined list *:—

Diplograptus folium, *His.*
—— palmeus, *Barr.*
Monograptus priodon, *Bronn.*
—— *bohemicus*, Barr.
—— *Rœmeri*, Barr.
—— *colonus*, Barr.
—— nuntius, *Barr.*
—— Halli, *Barr.*
—— Becki, *Barr.*
—— Nilssoni, *Barr.*
Monograptus *chimœra*, Barr.
—— *testis*, Barr.
—— spiralis, *Geinitz.*
—— turriculatus, *Barr.*
—— proteus, *Barr.*
Rastrites Linnæi, *Barr.*
—— fugax, *Barr.*
—— gemmatus, *Barr.*
—— peregrinus, *Barr.*
Retiolites Geinitzianus, *Barr.*

To judge from this catalogue the band E *e* 1 includes representatives of the Upper Birkhill, Gala, and Wenlock beds of Britain and Scandinavia, where the forms in italics are exclusively Wenlock and Ludlow species.

France.—The only Graptolitic strata of Llandovery age hitherto detected in France are portions of the *Ampelite-beds* of Anjou and Bretagne, &c. They form two consecutive groups, the *Schiste ampéliteux* and the *Calcaire ampéliteux*, both rightly referred by the French geologists to the Third Fauna of Barrande. These *Ampelite*-beds must include also strata of Wenlock age.

In the *Ampelite*-Schists of Maine et Loire M. Farge has collected†

Monograptus colonus, *Barr.*
—— Becki, *Barr.*
—— Nilssoni, *Barr.*
Monograptus spiralis, *Gein.*
Diplograptus folium, *His.*

From the higher zone with *nodules ampéliteux*, the representative of the *Ampelite*-Limestone of other districts, Messrs. Tromelin and Lebesconte‡ have obtained

Monograptus bohemicus, *Barr.*
—— Becki, *Barr.*
Monograptus priodon, *Bronn.*
Retiolites Geinitzianus, *Barr.*

In their catalogue of the fossils of Anjou and Bretagne these authors enumerate from the *Ampelite*-Schists §

Diplograptus folium, *His.*
Monograptus Becki, *Barr.*
—— colonus, *Barr.*
Monograptus Nilssoni, *Barr.*
—— spiralis, *Gein.*

Monograptus testis, Barr., is quoted from the *Ampelite*-Schists of the department of the Sarthe. If properly identified, I suspect this is from higher beds, of true Wenlock age.

* Barrande, Grapt. de Bohême, p. 18.
† Tromelin and Lebesconte, Catalogue Silurian Foss. 1875, p. 52.
‡ Idem ibid. § Ibid. Table A.

Spain.—Rocks of Llandovery age occur also in the southern districts of the Peninsula. Among the so-called Lower Silurian fossils enumerated by De Verneuil and Barrande as present in the Lower Palæozoic strata of Almaden and the Sierra Morena are found *

Monograptus spiralis, *Geinitz.*
—— Halli, *Barr.*
Monograptus priodon, *Bronn.*
Diplograptus palmeus, *Barr.*

America.—Throughout the United States and Canada the Llandovery strata consist almost wholly of coarse sandy non-fossiliferous beds or of calcareous rocks abounding in Brachiopoda, but destitute of Graptolites. The Clinton beds, which may be roughly paralleled with our Tarannon Shales, afford the peculiar American forms

Monograptus clintonensis, *Hall.*
Retiolites venosus, *Hall.*

Salopian (or Wenlock and Lower Ludlow) Formation.

The great Mudstone or Salopian formation of Shropshire is more or less graptolitiferous throughout. In a few localities its basal strata afford Rhabdophora in remarkable abundance. As we ascend the succession they gradually diminish in numbers, as a general rule. To this, however, there are exceptions. One of the most noticeable is that at the base of the Lower Ludlow, where, more especially in Hereford and Radnor, some of the beds are crowded with Graptolites. They are, however, of but few species, and belong to a single genus only. About the horizon of the Aymestry Limestone they vanish altogether; but whether this is due to the change in the composition of the strata, which here begins to take on a coarse sandy character, or whether it is owing to rapid extinction of the order, it is as yet impossible to determine.

(*a*) Zone of *Cyrtograptus Murchisoni*, Carr.

Wales.—The base of the Wenlock or Salopian series of the neighbourhood of Builth is formed of a few feet of calcareo-carbonaceous shales, crowded with fairly preserved Rhabdophora, among which the beautiful species *Cyrtograptus Murchisoni*, Carr., is especially conspicuous. It is associated with

Monograptus priodon, *Bronn.*
—— Halli, *Barr.*
—— vomerinus, *Nich.*
Monograptus colonus, *Barr.*
Retiolites Geinitzianus, *Barr.*

The same zone is probably present in the shales at the base of the Wenlock, on the banks of the Onny, near Plowden,

* De Verneuil et Barr. Bull. Géol. Soc. France, 1855, p. 964.

&c., where I have procured fragments of *Cyrtograptus Murchisoni*.

Lake District.—Throughout the Westmoreland region the zone of *C. Murchisoni* seems to overlie the *Pale Slates* proper, and to form the base of the Coniston series. From the lowest beds of the Coniston Flags near Broughton have been collected, either by Prof. Nicholson or myself*,

Cyrtograptus Murchisoni, *Carr.*
Monograptus priodon, *Bronn.*
—— Halli, *Barr.*
—— vomerinus, *Nich.*
Monograptus riccartonensis ?, *Lapw.*
—— colonus, *Barr.*
Retiolites Geinitzianus, *Barr.*

Sweden.—The same zone has been detected by Mr. G. Linnarsson at the base of the *Retiolites*-beds of Scania. From this zone at Rostånga Herr v. Schmalensee has collected †

Cyrtograptus Murchisoni, *Carr.*
Monograptus priodon, *Bronn.*
Monograptus vomerinus, *Nich.*
Retiolites Geinitzianus, *Barr.*

The same zone is recognizable in many other localities, always affording its characteristic fossils.

Bohemia.—Mr. Carruthers ‡ recognized *Cyrtograptus Murchisoni* in a collection of Graptolites forwarded by Barrande to the British Museum, London. Its true horizon in Bohemia is unknown.

(*b*) Higher Wenlock Strata.

Wales.—In the main mass of the Wenlock Shales, Graptolites are rarer than in the *Murchisoni* zone. Locally, however, they are abundant. From the Wenlock Shales, near Builth-Road Station, Radnorshire, I have collected

Cyrtograptus Linnarssoni, *Lapw.*
Monograptus colonus, *Barr.*
Monograptus Halli, *Barr.*
—— vomerinus, *Nich.*

The same forms occur in the Wenlock Shales of the valley of the Onny, above Horderly, the first named in fragments only.

Lake District.—In the higher Coniston Flags of the Lake District I have myself collected

Retiolites Geinitzianus, *Barr.*
Monograptus priodon, *Bronn.*
Monograptus vomerinus, *Nich.*
—— colonus, *Barr.*

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* Professor Hughes enumerates also *Monograptus Flemingii*, Salt., and *Monograptus latus*, M'Coy, from these beds (Mem. Geol. Survey England and Wales, Explan. Sheet 98, S.E., p. 11).

† Linnarsson, Obs. Grapt. Schists of Scania (Geol. Fören. Förhandl. 1879, p. 256).

‡ Carruthers, Geol. Magazine, vol. v. p. 128.

and in Prof. Nicholson's fine collection I recognized, as being also procured from these beds,

Monograptus Halli, *Barr.*
—— bohemicus, *Barr.*
Monograptus dubius, *Suess.*
—— riccartonensis, *Lapw.*

Scotland.—From the *Riccarton Beds* of the basin of the Solway, which stand generally in the place of the Wenlock of Siluria, the following forms have been collected by Mr. James Wilson or myself* :—

Retiolites Geinitzianus, *Barr.*
Cyrtograptus Carruthersi, *Lapw.*
Monograptus priodon, *Bronn.*
—— riccartonensis, *Lapw.*
Monograptus vomerinus, *Nich.*
—— colonus, *Barr.*
—— dubius ?, *Suess.*

Near Straiton, in the county of Ayrshire, beds probably belonging to the base of the Riccarton series afford

Monograptus vomerinus, *Nich.*
Cyrtograptus, sp.

From the Wenlock strata of Habbies Howe, in the Pentland Hills, Mr. Henderson † has collected

Retiolites Geinitzianus, *Barr.*
—— colonus, *Barr.*
Monograptus priodon, *Bronn.*
—— vomerinus, *Nich.*

Sweden.—According to the most recent communications of Mr. G. Linnarsson, the *Retiolites Skiffer* of Scania, which succeed the zone of *Cyrtograptus Murchisoni*, already referred to, fall into two main divisions ‡, viz. :—

(1) Strata with *Monograptus testis*, Barr.
(2) Strata with *Monograptus colonus*, Barr.

Near Jerrestad and Tomarp the dark grey schists with calcareous nodules that compose the "Strata with *Monograptus testis*" yield

Monograptus testis, *Barr.*
—— priodon, *Bronn.*
Monograptus colonus, *Barr.*
Cyrtograptus, sp.

The overlying "Strata with *M. colonus*" are comparatively barren greenish and grey schists, and have a wide geographical extension in Scania. They afford principally

Monograptus colonus, *Barr.*
—— priodon ?, *Bronn.*
Monograptus Barrandei, *Suess.*

and they are especially characterized by the presence of *Cardiola interrupta* (Brod.), which is unknown in the underlying Scanian formations.

Norway.—To this general Wenlock horizon probably

* Lapworth, Scottish Monograptidæ, Geol. Mag. 1876.
† Lapworth, Trans. Edinburgh Geol. Soc. 1874.
‡ Linnarsson, Observations on Graptolitiferous Schists of Scania (Geol. Fören. Förhandl. 1879, p. 256).

belong the Graptolitidæ figured by Prof. Kjerulf from his étage 8 of the Protcrozoic rocks of Christiania *. They include

Monograptus priodon, *Bronn.*
—— colonus ?, *Barr.*
Retiolites Geinitzianus, *Barr.*
Cyrtograptus, sp.

Bohemia.—The forms enumerated by Barrande from the Limestone beds of the étage E have a decidedly Salopian facies †. They are

Monograptus priodon, *Bronn.*
—— bohemicus, *Barr.*
—— Rœmeri, *Barr.*
Monograptus colonus, *Barr.*
—— chimæra, *Barr.*

France.—Among the fossils collected by M. de Grasset at Cabrières, near Neffiez (Hérault), in Languedoc ‡, the following Salopian group of Rhabdophora is noticed :—

Monograptus bohemicus, *Barr.*
—— priodon, *Bronn.*
Monograptus Rœmeri, *Barr.*

These are found, as usual, in association with *Cardiola interrupta* (Broderip).

(*c*) Lower Ludlow Beds.

Wales.—The distribution of the Rhabdophora in the Lower Ludlow rocks of Siluria was made the subject of special study by Mr. Hopkinson in 1873; and a brief summary of his conclusions was communicated to the British Association in that year. The results of my own hasty examination of these rocks during the summer of 1879 were in the direction of confirming his general conclusions, without adding any new facts of special importance.

According to Mr. Hopkinson the Lower Ludlow rocks of Leintwardine and its neighbourhood afford §

Monograptus colonus, *Barr.*
—— leintwardinensis, *Hopk. MS.*
Monograptus Salweyi, *Hopk. MS.*
—— Rœmeri, *Barr. &c.*

Of these, *Monograptus leintwardinensis* is most emphatically the characteristic fossil of the zone. I met with it in extraordinary abundance not only near Leintwardine, but also near Barrington, Adferton, and Vinnal, &c., near Ludlow. I met with it also in swarms, but indifferently preserved, in the Lower Ludlow of the neighbourhood of Presteign and New Radnor.

* Kjerulf, Veiviser, 1865, p. 31.
† Barrande, Graptolites de Bohême, p. 18.
‡ Tromelin et Lebesconte, Catalogue Foss. siluriens, 1875, p. 54.
§ Hopkinson, Geological Magazine, 1873, p. 520; ibid. 1875, p. 561.

Downtonian Strata.

Above the horizon of the Aymestry Limestone, which forms the divisional line between the Lower and Upper Ludlow groups of Murchison, no distinct species of Graptolite has yet been identified. Prof. Phillips * notices the presence of Graptolites in the Upper Ludlow of the Malvern Hills, but does not attempt their identification. Mr. R. Etheridge † catalogues a fragment of a Graptolite from the supposed Lower Old Red Sandstone of Lanarkshire. Mr. G. Linnarsson informs me that he has recently recognized a Graptolite in a collection of fossils from the Gothland Sandstone, which possibly corresponds to the lower part of the British Downtonian series.

[To be continued.]

VI.—*On the Action of Light and the Function of Chlorophyll in Plants.* By M. Pringsheim ‡.

My purpose in this preliminary communication is to state some results which I have obtained by a new and peculiar method of investigation in *concentrated sunlight.*

I have made use of this method for some years in order to gather experimental knowledge of the relations of light to the absorption of gases by growing plants, and of the part played therein by chlorophyll. Amid the confusion of contradictory opinions and statements which pervade the literature of the subject, after many vain endeavours to advance upon the path usually trodden, I felt myself bidden to proceed to the employment of *intensified light.* I hoped thus to be able in a short time to bring into view, and unequivocally to observe immediately in the cell, and directly under the microscope, the processes called forth in plants by the action of light.

In fact the experiments which have hitherto been made have laboured under the serious defect that too inconsiderable intensities of light were employed. This is especially true of those experiments in which it was endeavoured to prove that the different colours of the spectrum act differently upon plants. If plants are grown in diffused daylight, or even in direct sunshine behind coloured screens or coloured glasses or

* Phillips, Mem. Geolog. Survey, vol. ii.

† Etheridge, Mem. Geol. Survey Scotland, Explan. Sheet 23, p. 57.

‡ Translated from the 'Monatsbericht der königlich preussischen Akademie der Wissenschaften zu Berlin,' July 1879, pp. 532–546.